

APPENDIX A

LEO COVERAGE VARIABILITY

LEO Coverage Variability

Abstract

Several orbital constellations are compared below on the basis of "per cent of one day for which each of 6 sites can view one or more satellites in the constellation." This analysis and a few conclusions are presented to show that the different orbital element sets and constellation parameters considered by the FCC LEO applicants results in a wide variability in coverage.

Methodology

Six sites were used for all orbital simulations, as follows:

Site Name	Latitude (degrees)
80 degrees North Latitude	80
Point Barrow, Alaska	71.0
Seattle, Washington	47.3
Miami, Florida	25.7
Puerto Rico	18.3
Pontianak, Borneo	0.0

The "Chains" feature from Satellite Tool Kit from Analytical Graphics was used to simulate satellite visibility "accesses" of the entire constellation from each site (one at a time), which were then or'ed together to calculate start and stop times for each interval for which 1 or more satellites were visible at the specified site elevation angle. For simplicity of comparison, only circular ($e=0$) orbits were used. A variety of circular Walker constellations of 48 and 40 satellites were simulated at 1000 and 2000 altitudes with otherwise identical parameters, as follows:

Case/Reference #	Altitude (KM)	Inclination (deg)	#planes x #S/C ea
1	1000	52	6 x 8
2	2000	52	6 x 8
3	1000	90	6 x 8
4	2000	90	6 x 8
5	1000	52	8 x 6
6	2000	52	8 x 6
7	2000	52	5 x 8
8	2000	90	5 x 8

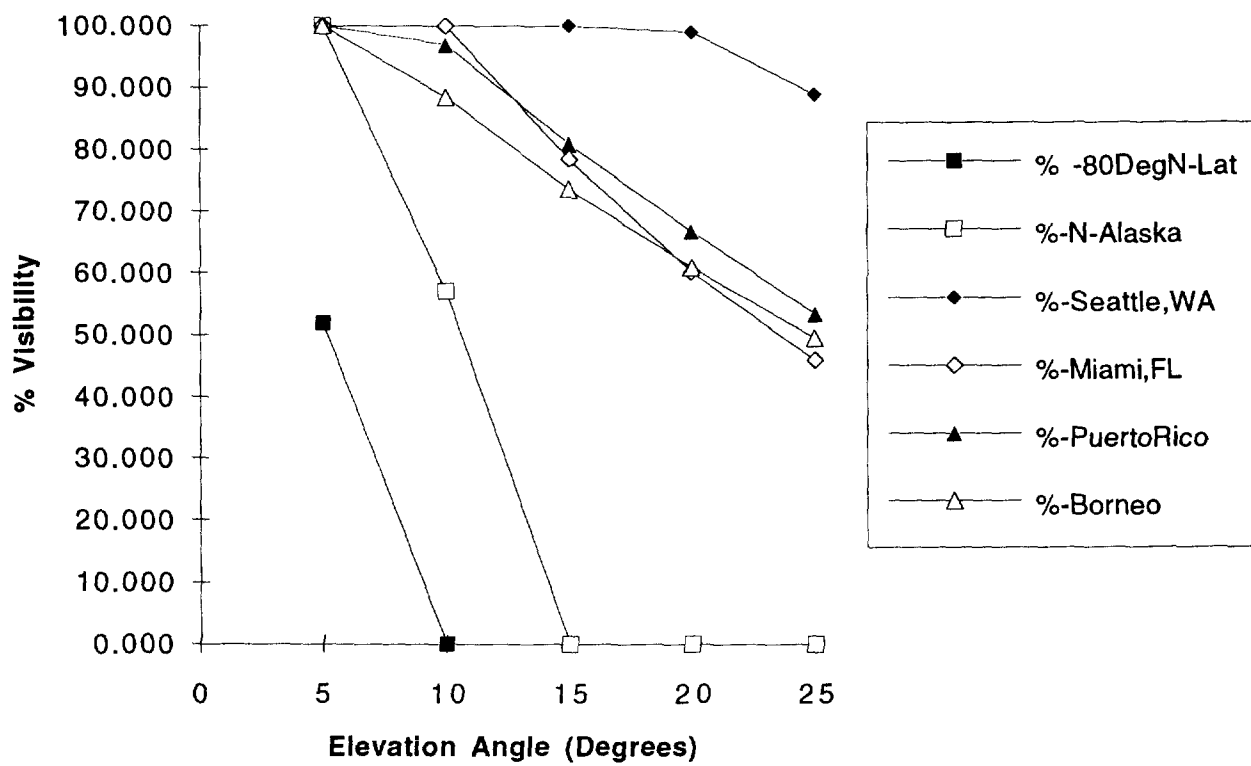
A few simulations were made over a 3 day simulation, with comparable results within an accuracy of 2 minutes total visibility per day.

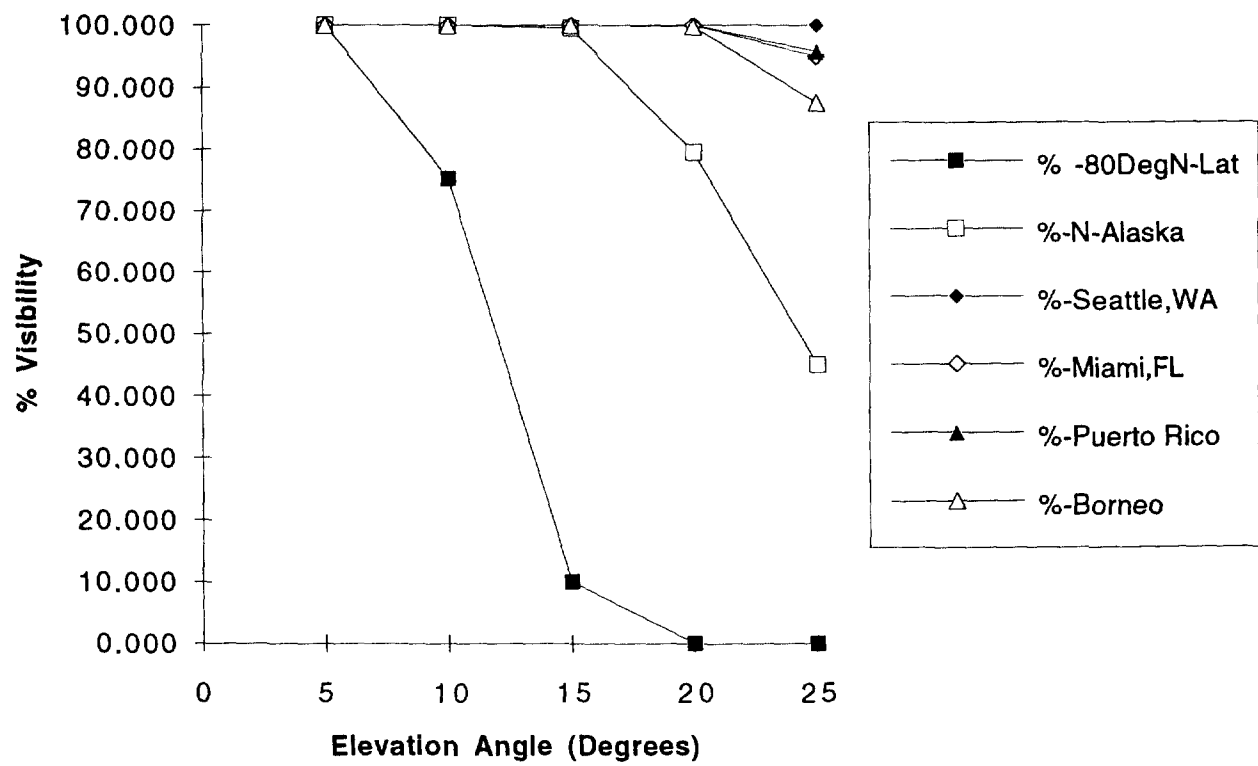
Results

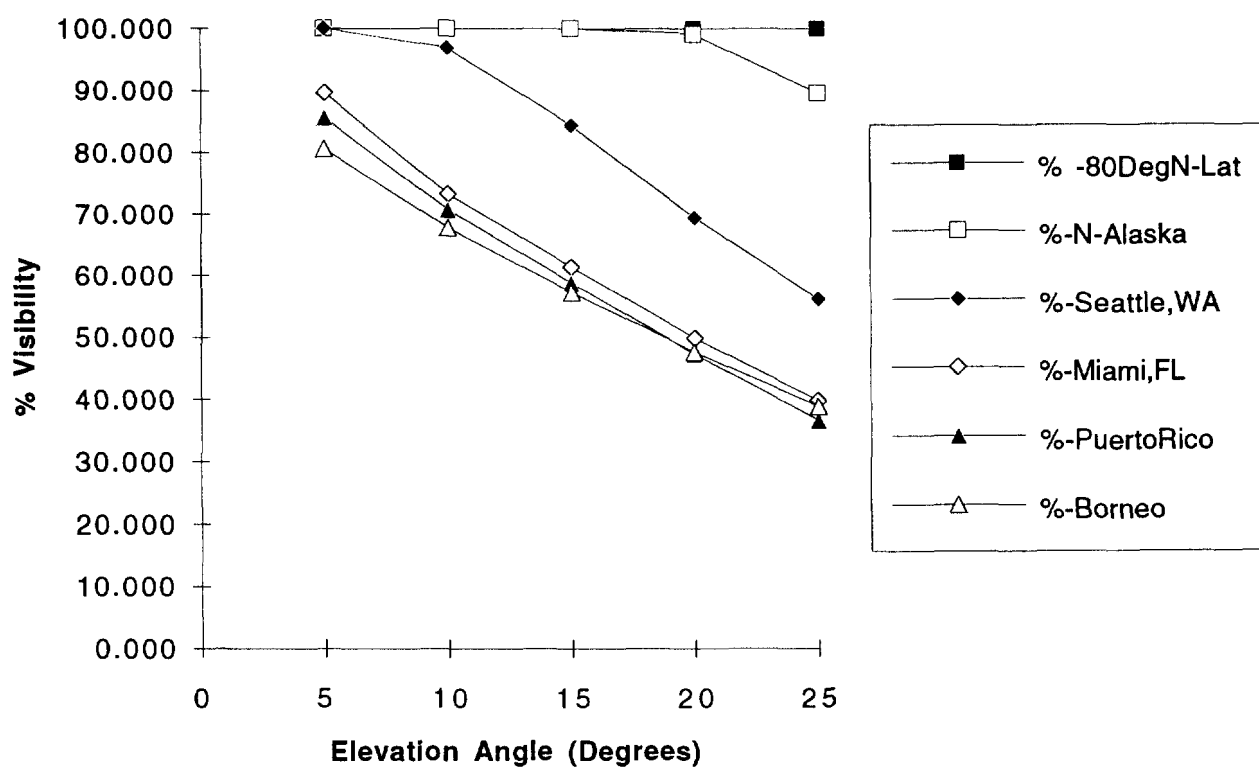
The 8 cases are plotted below for reference from this section. Note that in some cases such as 100 % coverage, some of the plot legend symbols are obscured by the symbol which is "on top." Comparing cases 1 and 2, the CONUS north/south boundary sites (Seattle and Miami) illustrate notably poorer coverage at 1000 KM. whereas 2000 KM coverage % is good, even at 25 degree elevation. Cases 3 and 4 show significant coverage improvement at both altitudes, by going to a polar orbit. A generally more expensive way of achieving a 48 satellite constellation is the case 5 and 6 8x6 constellation, requiring launches into 8 planes, rather than the prior 6 planes. The 8x6 gives slightly better coverage. Cases 7 and 8 show two 5x8 constellations, at 2000 KM each, and for inclinations of 52 and 90 degrees. The case 7 5x8 constellation at 52 degrees inclination gives almost as good coverage as the comparable case 2 6x8 constellation. The Case 8 polar constellation is notably better than Case 7 for north Alaska and for 80 degree north latitude.

Conclusions

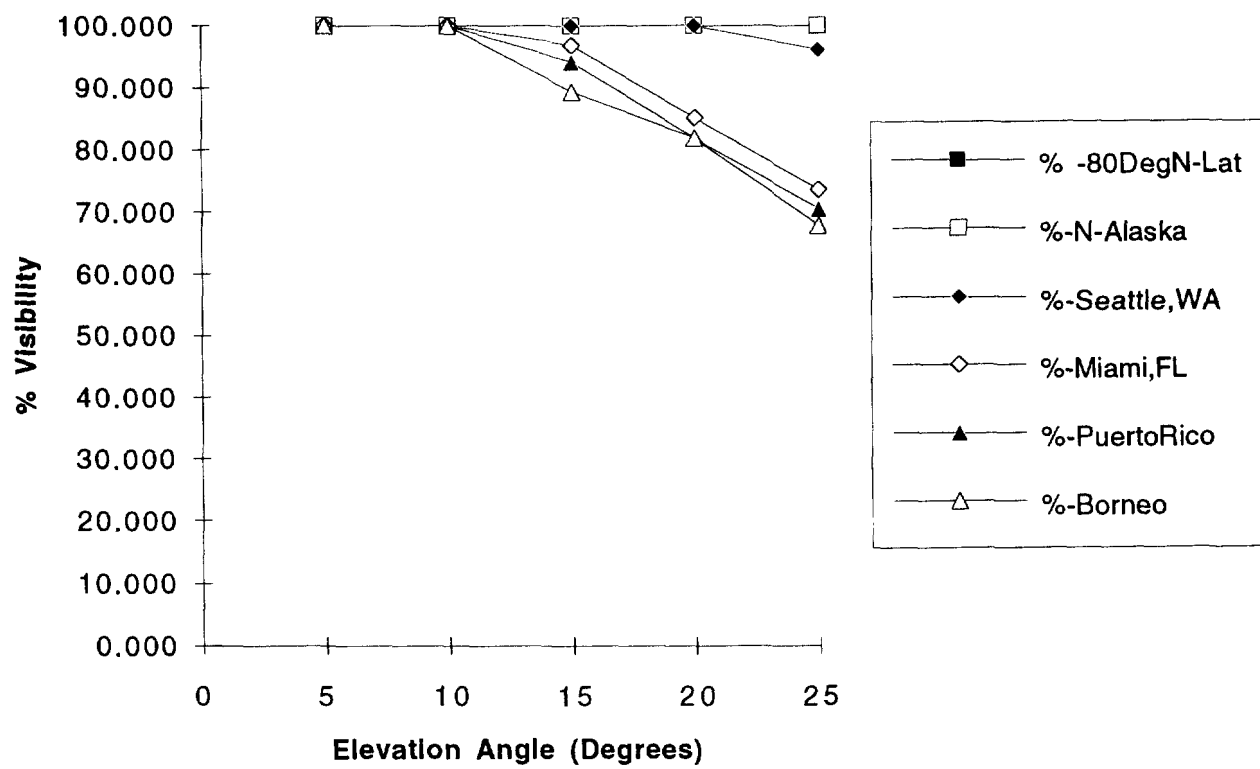
- A given number of satellites can form a constellation in many different ways, with widely varying number of planes (and related launch costs), and with widely varying coverage.
- Inclination affects coverage, and points out the criticality of possibly placing less stringent requirements on "80 degrees latitude" and on the northern slopes of Alaska, to obtain otherwise good coverage and lower launch costs at moderate inclination angles.
- Due to the wide variety of LEO applicant orbital configurations, we recommend that the FCC carefully consider coverage requirements so that they are minimally restrictive on the applicants. It would not be productive to place requirements which unduly raise constellation, launch, or other costs. Some relaxation of coverage for the northern slopes of Alaska is desirable.

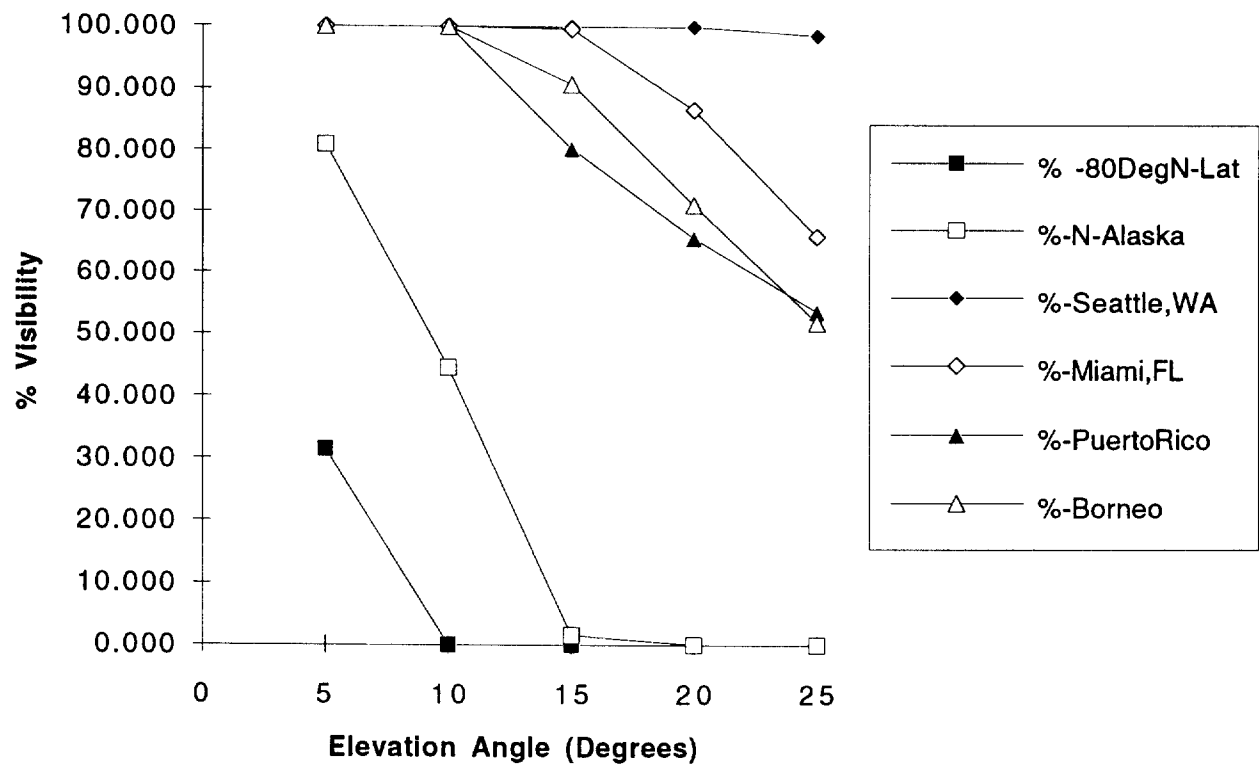
1000 KM, $i=52$, $e=0$, 6x8 Walker Constellation Visibility

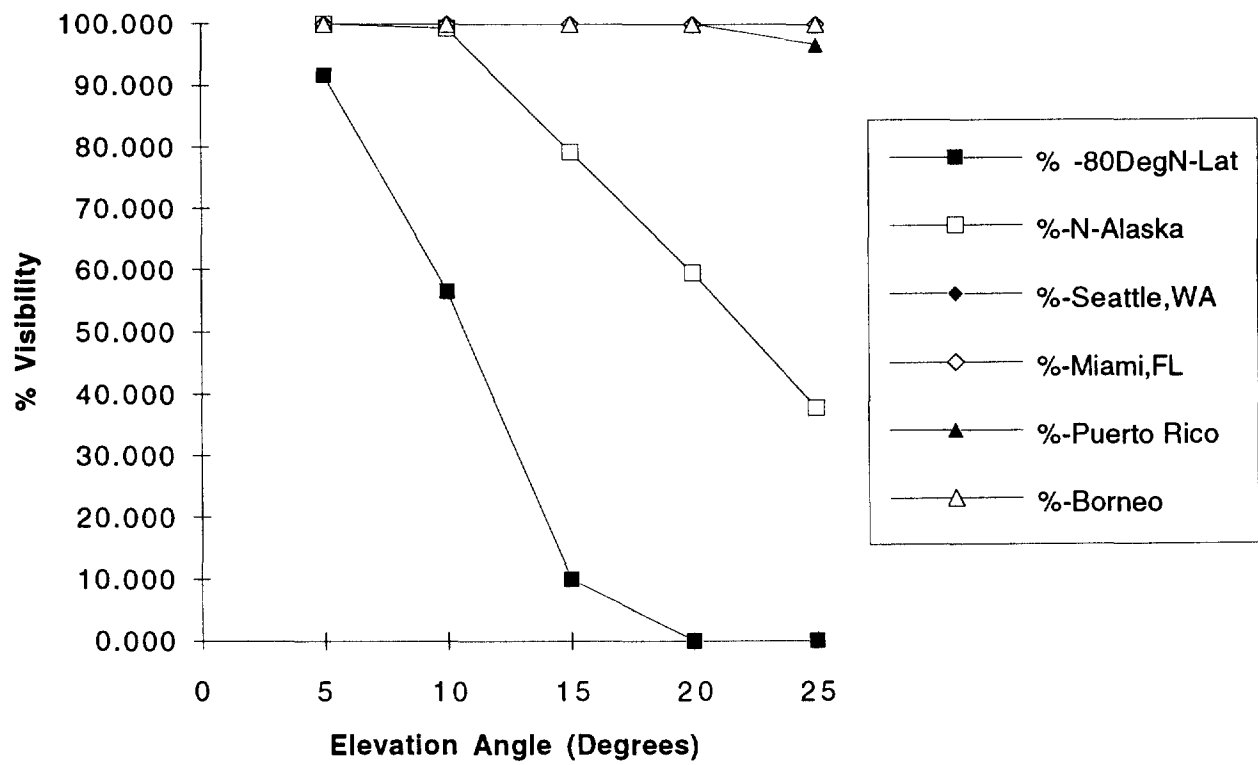
2000 KM, i=52 e=0, 6x8 Walker Constellation Visibility

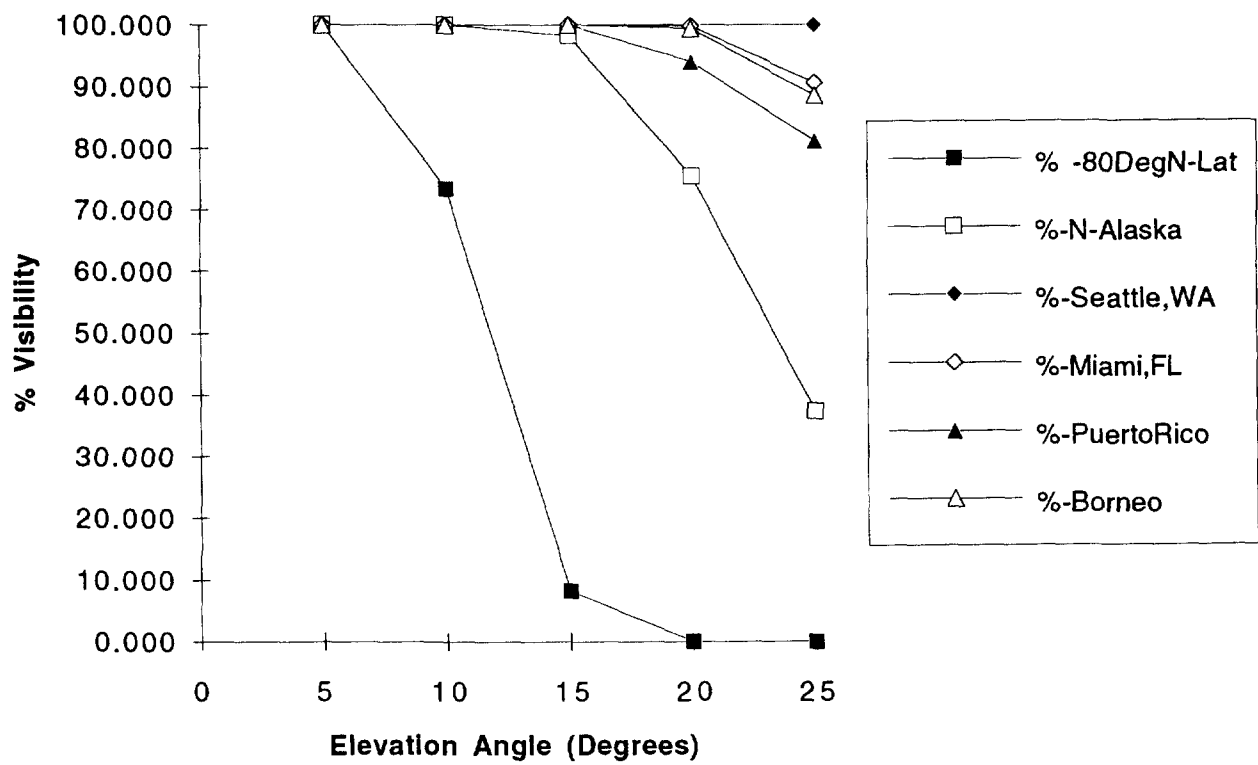
1000 KM, $i=90$; $e=0$; 6x8 Walker Constellation Visibility

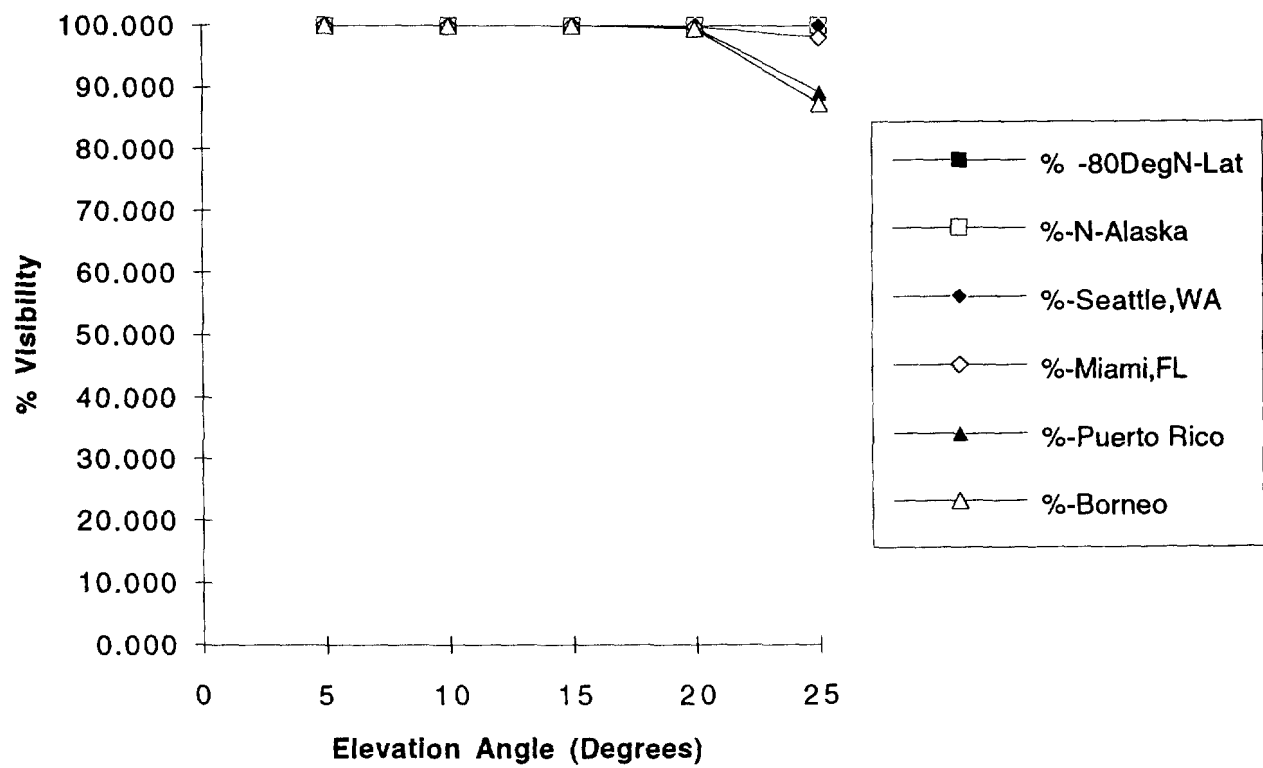
2000 KM; i=90; e=0; 6x8 Walker Constellation



1000 KM; i=52; e=0; 8x6 Walker Constellation Visibility

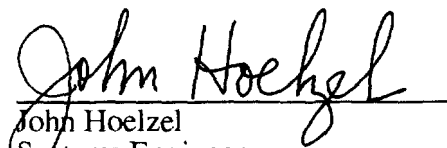
2000 KM; i=52; e=0; 8x6 Walker Constellation Visibility

2000 KM; i=52; e=0; 5x8 Walker Constellation Visibility

2000 KM; i=90; e=0; 5x8 Walker Constellation Visibility

Engineer's Certification

The undersigned hereby certify that they are technically qualified persons responsible for the preparation of the engineering information contained in the Appendix, that they have either prepared or reviewed the information contained herein, and that it is complete and accurate to the best of their knowledge.

A handwritten signature in black ink, reading "John Hoelzel", written over a horizontal line.

John Hoelzel
Systems Engineer
E-Systems/Garland Division
P. O. Box 660023
Dallas, Texas 75266